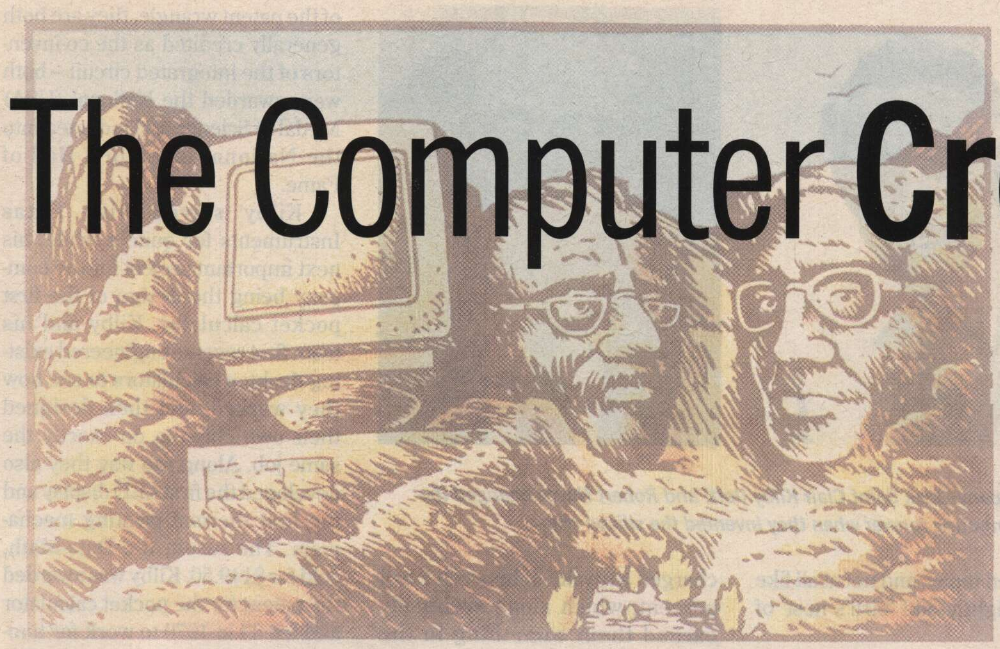
The Computer **Creators**



Mike James looks at the work of Jack Kilby and Robert Noyce, the men behind the microchip

Should we include the inventor of every important electronic device in our list of computer creators? Should the man who invented the valve, John Flemming, be given a place in the history of computing? Probably not, but the use of silicon to create integrated circuits is so central to the modern computer that the situation there is very different. After all, it's doubtful that the chip would have been worth inventing at all if it wasn't for its potential use in computers. It's certain that computers would still be rare without the silicon chip. So close are the two that when the personal computer was first introduced, it was very common for the press to become quite confused about the identities of the microchip and the microcomputer revolution. Interestingly, the technology of the microchip was invented by two people – Jack Kilby and Robert Noyce.

File card: Jack Saint Clair Kilby/Robert Noyce

Jack Saint Clair Kilby	
Lived:	1923-present
Country:	USA
Specialism:	Electronics
Theories:	None
Products:	The integrated circuit and the pocket calculator
Companies:	Texas Instruments

Robert Noyce	
Lived:	1927-1990
Country:	USA
Specialism:	Electronics
Theories:	None
Products:	The integrated circuit
Companies:	Fairchild, Intel

The first electronic computers were huge, because the individual active elements – the valves – used to make them were large and the interconnecting wiring needed space. The very size limited the power of the machine in two different ways. The first limitation was the sheer volume needed for a machine with a large number of active elements; the second was the time it took for signals to travel along the connecting wires. These were two vital reasons why the size of a computer had to be reduced before it could become really useful.

The first step in reducing total machine size was to reduce the size of the active element, which was done by using transistors. However, this did very little for the interconnection problem. Being able to cram more active devices into the same space simply increased the number of connections to be made. The more you crammed in, the higher the number of required connections became. This became known as the 'tyranny of numbers', and it had to be solved to allow the computer to progress.

When William Shockley, one of the inventors of the transistor, set up shop in what was to become Silicon Valley, he recruited the best people he could find. Robert Noyce was so confident that he'd be among the chosen few that he rented a house near the company before the interview! However, he didn't stay with Shockley for long – in 1958 he and a group of engineers left to found Fairchild. It's an interesting footnote that they each invested $500 in this new company.

At about the same time, Jack Kilby had just started with Texas Instruments – a company definitely not located in Silicon Valley. At the time, TI was trying to make a name for itself in the defence business. One of its projects was to produce a sort of electronic 'Lego', in which the components would be fitted into some kind of standard connector which could then be pushed together to make circuits. TI had a policy that everyone took their holiday at the same time, but Kilby hadn't worked long enough to be entitled to a holiday, so he worked on while the plant was shut down. He knew he would be working on the Micro-Module project when the holiday was over and he didn't think it would work. So he tried to find an alternative.

In his previous job, Kilby had been involved in a plan to place components on a ceramic base, so perhaps this was the spark that gave rise to his good idea, which was to build everything on a single piece of silicon. With the benefit of hindsight, that now seems less of a leap of the imagination, but that's because we don't suffer from the preconception that a different material is needed for each type of component – that carbon makes resistors; ceramic and metal make capacitors; copper makes connecting wires and inductors; and germanium or silicon make transistors. At the time, the idea of trying to make everything out of germanium, or the then new silicon, seemed a bit silly. But Kilby ➧

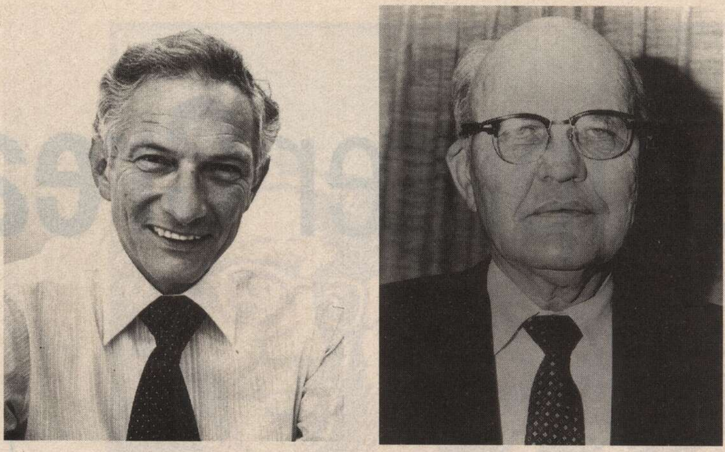
worked out that it could be done. The start was a silicon resistor – an undoped strip of silicon; then came a silicon capacitor – a reverse biased diode. The beauty of the idea was that the components could all be made on the same slice of semiconductor material, complete with transistors and wiring.

When the TI holiday was over, Kilby was given the go-ahead to try the idea – but only after he demonstrated that each of the components he described could indeed be made. Working alone, he hand-carved a piece of silicon to make a resistor and used a standard p-n junction to show that the capacitor worked. The next step was to make everything on a single chip. The material he used was germanium, while the internal connections between the components were made by hand-applied gold wires. This made the first working integrated circuit – a phase shift oscillator. It looked like a bird's nest in miniature... but it worked.

Circuit training

Robert Noyce should have come to the single chip solution earlier than he did, perhaps even earlier than Kilby. After all, his firm, Fairchild, was making modern-style transistors – a large wafer subjected to diffusion on both sides to make a PNP or an NPN structure. The company then chopped up the wafer, connected wires to the slices and placed a can over each one. The idea of wiring up the transistors on the wafer should have occurred sooner, but it took one other step.

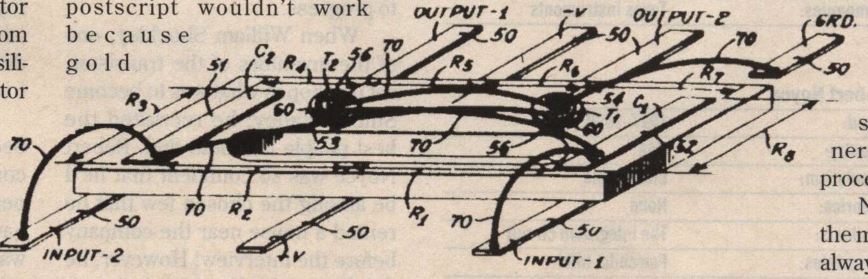
Jean Hoerni, one of the other founders of Fairchild, had come up with the idea of the planar transistor – a flat PNP junction insulated from the outside world by a layer of silicon dioxide. The planar transistor was invented to overcome problems of contamination, but Noyce started to think about the way metal strips could be laid down on top of the insulating layer to connect separate planar transistors together. After inventing the connection method, he went on to think about resistors and capacitors, discovering that it was possible to put it all together on one piece of silicon. Noyce was six months behind Kilby, but his version of the idea was arguably more complete. He even sketched the design of an adder built onto a single chip, although it would be a few years before the technology got that far. His concept of the integrated circuit was essentially one that would be recognised today, and not at all like Kilby's slightly odd 'bird's nest' of wires.



Two's company: Jack Saint Clair Kilby (left) and Robert Noyce changed the face of computing forever when they invented the silicon chip

Patently obvious

Although Kilby probably thought of the integrated circuit before Noyce, both Texas and Fairchild filed for patents and a long legal wrangle developed between the two. One of the key points of contention was the use of flying interconnecting wires in the Kilby diagram – was it really a true integrated circuit? Kilby recognised the problem while the patent was being written and added some lines about being able to use any method of interconnection – for instance, gold tracks laid down on an insulating layer of silicon dioxide. Where this additional idea sprung from is unknown, but it certainly placed Kilby's chip alongside Noyce's in terms of sophistication. The patent lawyers argued that Kilby's postscript wouldn't work because gold wouldn't stick to silicon dioxide, and even went as far as using experts to try to undermine Kilby's design. Despite this, the patent was initially awarded to Kilby, or rather Texas Instruments. But roughly 10 years on, in 1966, the appeal judge reversed the decision and awarded the patent to Noyce – in other words, Fairchild.



The drawing used in the patent of Kilby's chip

By that time it didn't make any difference, because the two firms had got together to carve up the market between them. They each charged a royalty of between 2 to 4 percent, which alone eventually earned them something in the region of $100 million each. I say "eventually", because there were few takers in 1959 when both companies announced the technique. This was mainly due to the high price of the relatively low component count chips that could be made. It was cheaper to build the same out of discrete components.

Surprisingly, it wasn't the mainstream computer industry that initially created the market for integrated circuits – it was the space race and military electronics that demanded their low weight and reliability at any price. As the price fell and the number of components increased – a trend that continues today – mainframe computers started to incorporate replacement printed circuit boards using chips in place of transistors. Later, whole integrated circuit computers were designed, and these were followed by the minicomputer and microcomputer. These developments have led to major advances in computing, and we are still waiting to see where it will all end.

A calculated risk

So what happened to Kilby and Noyce? Irrespective of the outcome of the patent wrangle, they are both generally credited as the co-inventors of the integrated circuit – both were awarded the National (USA) Medal of Science and inducted into the National Inventor's Hall of Fame.

Kilby stayed with Texas Instruments for quite a while, his next important project for the company being the design of the first pocket calculator. Kilby and his team first reverse engineered existing desktop calculators to see how they worked, and then designed their own chips to do exactly the same job. Along the way they also developed the first LED display and the first thermal printing mechanism. The result, the Data-Math, sold for $149.50. Kilby was awarded the patent for the pocket calculator and left TI in 1970 to work for himself as an independent inventor. But although he clocked up a number of patents, none seem to have made him rich or any more famous.

In the mid-1960s, Noyce was growing increasingly unhappy at Fairchild, and in 1968 he and Gordon Moore left to found Intel. They set out to make computer circuits on silicon – the rest is history. Perhaps the strangest twist to the story is that Noyce handed the task of designing the chips for Busicom's new desktop calculator to an engineer by the name of Ted Hoff. He managed to cram the logic onto a single chip, thus producing the world's first microprocessor. Ironically, Busicom's machine was knocked out of the marketplace by Jack Kilby's cheaper pocket model and its subsequent clones. As a result, Busicom couldn't pay Intel for the design work, so the rights to the chip returned to Intel, which promptly placed it on open sale as the 4004 – the forerunner of the entire 80X86 line of processors.

Noyce moved ever more into the management side of things, but always remained a techie at heart. Some of his financial decisions are certainly worth recording – he once warned his wife that she should not invest in a 'no-future' company down the road at Cupertino (Apple Computer, in fact) and then went and sank money into Osborne Computers, which made the first ever portable (well, luggable) machine. Osborne promptly went bankrupt and Mrs Noyce's investment sank along with the company. But then again, I suppose the president of Intel could afford to make such mistakes. ■